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## COOLING SYSTEM FOR THIN PROFILE ELECTRONIC AND COMPUTER DEVICES

### FIELD OF THE INVENTION

The present invention relates to an apparatus and method for cooling high heat dissipating components within electronic and computer system enclosures. More particularly, the invention relates to a cooling system for removing heat from high heat dissipating components located within small form factor consumer electronic and computer systems.

### BACKGROUND OF THE INVENTION

Integrated circuits (ICs) are typically housed within a plastic or ceramic package. The packages have leads or surface pads that are soldered to a printed circuit board. The circuit board and package are often located within an enclosed computer chassis that contains other circuitry associated with the computer system such as peripherals, memory cards, video cards, power supplies, etc..

It is desirable to have a high rate of heat transfer from the IC package in order to maintain the junction temperatures of the IC within safe operating limits. Modern microprocessors typically employ millions of transistors in internal circuitry that require some type of cooling mechanism, otherwise, excessive junction temperatures may affect the performance of the circuit and cause permanent degradation of the device. Hence, as the performance of integrated circuits continue to expand, the need to provide more efficient, reliable and cost effective heat removal methods has become increasingly important in the design of computer system enclosures and particularly in small general purpose computer systems, such as laptop and notebook computers. There also exists a need to remove heat from high-power profile components located within other small form factor or thin profile electronic devices.

High heat dissipating components located within the small confines of some consumer electronic devices may create "hot spots" at certain locations along the external casing of the device. These hot spots may be uncomfortable to the touch and, in some cases, may cause injury. Therefore, it is desirable to dissipate heat away from high heat generating components located within the enclosure of small form factor devices in such a way as to keep the internal components within their specified operating temperature range and to preclude the creation of hot spots along the exterior of the enclosure.

A number of prior art methods have been used to remove heat from heat generating components located within the confines of a computer system enclosure. For example, the method of cooling integrated circuit devices within notebook computers has evolved from the simple attachment of a finned heat sink to the top surface of the device, to the development of finned heat sinks having integral fans. More recent developments have include the use of large, flat heat spreading plates. In such applications, the integrated circuit (generally, the CPU) is directly or indirectly attached to a metal plate having a large thermal mass and a large heat transfer surface area. In some instances, the integrated circuit is thermally coupled to the heat spreading plate by a heat pipe or other low resistance thermal path. More recently, forced cooling air has been used to cool one side of a heat spreading plate having an integrated circuit attached to the other side. Although these heat transfer methods have proved sufficient in the past, they do not provide the heat removal capacity and/or efficiency needed to cool current and future high-performance microprocessors in portable general-purpose computers and other thin profile electronic devices.

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What is needed then is an apparatus and method which solves the aforementioned problems associated with cooling internal electronic circuits located within portable consumer electronic and computer devices. Particularly, what is needed is a highly efficient cooling system that is conformable to the size and power consumption restrictions imposed by small form factor and thin profile electronic devices, such as, for example, notebook computers.

### SUMMARY OF THE INVENTION

An apparatus and method for removing heat from a heat generating component located within a thin-profile consumer electronic or computer system enclosure is disclosed. In one embodiment the cooling system of the present invention includes an air duct comprising a thermally conductive housing having internal fins dispersed along the internal walls of the duct. An air flow generator produces an air flow that is directed from an inlet port located at or near the center of the air duct to first and second exit ports located adjacent opposite ends of the duct. A low resistance thermal path, such as a heat pipe, transfers heat from the heat generating component to the air duct housing.

### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and is not limited by the figures of the accompanying drawings, in which like references indicate similar elements, and in which:

FIG. 1A illustrates a perspective view of a heat exchanger according to one embodiment of the present invention.

FIG. 1B illustrates the air flow into and out of the heat exchanger depicted in FIG. 1A.

FIG. 2 illustrates a partial cut-away top view of the heat exchanger depicted in FIG. 1A.

FIG. 3 illustrates a side view of the heat exchanger shown in FIG. 2 along lines 3—3.

FIG. 4 illustrates a perspective view of a heat exchanger according to another embodiment of the present invention.

FIG. 5 illustrates a cooling system according to one embodiment of the present invention.

FIG. 6A illustrates a side view of a portable computer according to one embodiment of the present invention.

FIG. 6B illustrates a view of the back side of the portable computer shown in FIG. 6A.

FIG. 7 illustrates a side view of a portable computer according to another embodiment of the present invention.

FIG. 8 illustrates a top view of a heat exchanger in accordance with another embodiment of the present invention.

### DETAILED DESCRIPTION

An apparatus and method for removing heat from a heat generating component located within a thin-profile consumer electronic or computer system enclosure is described. In the following description, numerous specific details are set forth such as material types, dimensions, processing steps, etc., in order to provide a thorough understanding of the present invention. However, it will be obvious to one of skill in the art that the invention may be practiced without these specific details. In other instances, well known elements and processing techniques have not been shown in particular detail in order to avoid unnecessarily obscuring the present invention. In order to illustrate the need for cooling systems that are capable of being integrated within

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an enclosure having limited available space, this discussion will mainly be limited to those needs associated with removing heat from integrated circuits housed within portable computers, such as notebook and laptop computers. It will be recognized, however, that such focus is for descriptive purposes only and that the apparatus and methods of the present invention are applicable to other thin profile or small form factor electronic devices.

FIG. 1A illustrates a perspective view of a heat exchanger assembly 10 in one embodiment of the present invention. Heat exchanger 10 includes an air duct 11 consisting of an upper plate 12 and a lower plate 14. Plates 12 and 14 are constructed of a thermally conductive material, such as aluminum. An air generating device 16 is positioned within an opening 13 located at or near the center of upper plate 12. Threaded fasteners 22 are generally used to attach the two plates. In the embodiment of FIG. 1A, an integral clamp structure 24 is provided for attaching a heat pipe or other similar device to the heat exchanger housing. In this manner heat may be transferred from a remotely located heat generating component to heat exchanger 10. It is appreciated, however, that other devices that are capable of providing a low resistance thermal path from the heat generating component to the heat exchanger housing may also be used.

As shown in FIG. 1B, an air flow 32 is produced by air generating device 16 and directed into air duct 11 through opening 13. Inside the air duct, air flow 32 is split into two separate air flow streams 34 and 36. Air flow streams 34 and 36 are directed toward exit ports 18 and 20 located adjacent opposite ends of the air duct. FIG. 2 shows a partial cut-away view of the heat exchanger illustrated in FIG. 1A. FIG. 3 shows a cross-sectional view of the heat exchanger along lines 3—3. As depicted in FIGS. 2 and 3, fins 50 and 52 are positioned along the internal walls of plates 12 and 14, respectively. Fins 50 and 52 are typically arranged in a corresponding relationship so as to form small air channels within air duct 11. The fins, in combination with the thin profile of the air duct, act to enhance the air velocity through the air duct and to promote the mixing of air flow streams 34 and 36 with boundary film layers formed along the inner walls of plates 12 and 14. Such mixing tends to break up or thin the boundary film layers formed along plates 12 and 14 and, as a result, greatly increases the rate of heat transfer between plates 12 and 14 and air flow streams 34 and 36. Fins 50 and 52 also increase the effective heat transfer surface area between air flow streams 34 and 36 and plates 12 and 14.

As noted earlier, modern microprocessors employ millions of transistors in internal circuitry and operate at ever increasing speeds. As a result, the amount of heat generated by modern microprocessor components has increased significantly. Particular problems arise when these components, and other high heat generating components, are placed within constrained compartments, such as portable computer enclosures. The cooling system of the present invention provides a highly efficient, low power consuming, heat exchanger apparatus that is adaptable to the small confines of a portable computer enclosure. In one embodiment, the heat exchanger 10 comprises an air duct 11 and fan 16 assembly that is connectable to a passive heat transfer device, such as a heat pipe, by clamp 24. Fan 16 comprises a miniature, low power consuming axial flow fan having blades 17 that draw cool air into air duct opening 13. As shown in FIG. 3, fan 16 includes a hub 21 that houses a motor, a rotor 19 and blades 17. A control circuit is generally included within the fan assembly. The overall diameter of fan 16 is approximately 25 mm. The air flow generated by fan

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16 is directed down toward lower plate 14. The air flow impinges lower plate 14 and is split into two separate flow streams that are directed in opposite directions along the length of the air duct. In one embodiment, air duct 11 has a thickness, length and width of 7 mm, 30 mm, and 144 mm, respectively. The fins 50 and 52 formed along the inner walls of plates 12 and 14 are generally spaced equidistantly and have a rectangular cross-section of 1.3 mm by 2.0 mm. The air flow channels formed by fins 50 and 52 typically have a width of approximately 2 mm. As discussed above, the unique configuration of heat exchanger 10 provides a high efficient cooling apparatus that may be used in a variety of portable electronic devices.

FIG. 4 illustrates another embodiment of the present invention wherein an air flow 42 is directed into the air duct through an opening 43 in the upper plate of the assembly. Air flow 42 is split into two separate air flow streams 44 and 46 and directed through the air duct in the same manner described above in conjunction with the embodiment of FIG. 1A, except that air flow streams 44 and 46 are exhausted at points along the side ends 45 and 47 of the air duct.

With reference to FIG. 5, an apparatus for transferring heat from an integrated circuit package 80 to a heat exchanger 60 according to the present invention is shown. In accordance with one embodiment of the invention, a heat pipe 70 comprising an evaporator portion 71 and a condenser portion 72 is used to transfer heat from integrated circuit 80 to the heat exchanger housing. The evaporator portion 71 of heat pipe 70 is typically embedded within a copper or aluminum mating plate (not shown) that is preferably attached directly to the integrated circuit 80. In some applications, the mating plate is attached to the back side of a printed circuit board containing the integrated circuit. In those situations, the integrated circuit is thermally coupled to the mating plate through solid metal vias or through a copper slug embedded within the printed circuit board. The heat pipe 70 typically contains a fluid that flows along a wick (not shown) attached to the inner surface of the pipe. Heat is applied to the evaporator portion 71 of the pipe that is adjacent to package 80 and removed from the condenser portion 72 of the pipe that is coupled to heat exchanger 60. The heat vaporizes the fluid which creates a pressure differential between the evaporator portion 71 and condenser portion 72 of heat pipe 70. The pressure differential pumps the fluid through the wick from the condenser portion to the evaporator portion. The vaporized fluid is then pumped from the evaporator portion 71 back to the condenser portion 72. Pursuant to the present invention, heat is transferred from the condenser portion 72 of heat pipe 70 to the thermally conductive housing of heat exchanger 60. The heat is then transferred away from the heat exchanger by directing a cool air flow into and through the heat exchanger air duct in the manner described above, and exhausting the air flow into the surrounding environment. Heat pipe 70 may be attached to heat exchanger 60 with the use of an integral clamp structure. In such an instance, a thermal grease is applied at the clamp and heat pipe interface to enhance the heat transfer rate between the two components. Other attachment methods may also be used. For example, the condenser portion 72 of heat pipe 70 may be bonded to heat exchanger 60 with a high thermal conductive adhesive.

Turning now to FIG. 6A, a cooling system of the present invention is shown housed within a portable computer system enclosure 120. As illustrated, heat exchanger 110 is positioned such that cool air 118 is directed into the heat exchanger air duct along the top surface of the computer casing. Heated air 119 is exhausted from heat exchanger 110